Statistical physics of active matter: microswimmers in complex environments

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Differently from passive Brownian particles, active particles, also known as self-propelled Brownian particles or microswimmers and nanoswimmers, are capable of taking up energy from their environment and converting it into directed motion. Because of this constant flow of energy, their behavior can be explained and understood only within the framework of nonequilibrium physics. In the biological realm, many cells perform directed motion, for example, as a way to browse for nutrients or to avoid toxins. Inspired by these motile microorganisms, researchers have been developing artificial particles that feature similar swimming behaviors based on different mechanisms. These man-made micromachines and nanomachines hold a great potential as autonomous agents for health care, sustainability, and security applications. With a focus on the basic physical features of the interactions of self-propelled Brownian particles with a crowded and complex environment, this talk will discuss the basic principles, the development of artificial self-propelling microparticles and nanoparticles, and their application to the study of nonequilibrium phenomena, as well as the open challenges that the field is currently facing [3]. In particular we discuss some recent advances in this rapidly developing field including:
i) active Brownian articles in externally steered motility landscapes [1]: Many microorganisms, with phytoplankton and zooplankton as prominent examples, display phototactic behaviour, that is, the ability to perform directed motion within a light gradient. Here we experimentally demonstrate that sensing of light gradients can also be achieved in a system of synthetic photo-activated microparticles being exposed to an inhomogeneous laser field. We observe a strong orientational response of the particles because of diffusiophoretic torques.
ii) fission and fusion in magnetic microswimmer clusters [2]:
Fission and fusion processes of particle clusters occur in many areas of physics and chemistry from subnuclear to astronomic length scales. Here we study fission and fusion of magnetic microswimmer clusters as governed by their hydrodynamic and dipolar interactions. Rich scenarios are found that depend crucially on whether the swimmer is a pusher or a puller. Our predictions are obtained by computer simulations and verifiable in experiments on active colloidal Janus particles and magnetotactic bacteria.

[l] C. Lozano et al, Nature Communication **7**, 12828 (2016).
[2] F. Guzman-Lastra et al, Nature Communication **7**, 13519 (2016).
[3] C. Bechinger et al, Rev. Mod. Phys. **88**, 045006 (2016).